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Aeronautical Mobile Satellite Service (AMSS) Test Plan

May 1991

DOT/FAA/CT-TN91/20

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US Department of Transportation
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16. Abstract

This plan describes a test program which will be conducted by the Federal Aviation Administration (FAA) to support the validation of Standards and Recommended Practices (SARPs) being developed for the Aeronautical Mobile Satellite Service (AMSS) by the International Civil Aviation Organization (ICAO).

It also contains a description of the Communications Test Facility (CTF) which will be used to perform the tests. An appendix includes a brief description of each test to be performed along with setup and data to be recorded.

17. Key Words
Aeronautical Mobile Satellite Service (AMSS)
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EXECUTIVE SUMMARY

This document describes the Test Program and the Communications Test Facility (CTF) developed to assess and document the performance of the Aeronautical Mobile Satellite Service (AMSS). The CTF will be used to conduct the tests required to validate Standards and Recommended Practices (SARPs) prepared by the International Civil Aviation Organization (ICAO) and Minimum Operational Performance Standards (MOPS) developed by the Radio Technical Commission for Aeronautics (RTCA).

1. INTRODUCTION.

1.1 OBJECTIVE.

The objective of the Federal Aviation Administration (FAA) Aeronautical Mobile Satellite Service (AMSS) test program is to validate the International Civil Aviation Organization (ICAO) AMSS Standards and Recommended Practices (SARPs) and to assess the performance of the AMSS system. Secondary objectives include:

a. Evaluation of the ability of AMSS to transmit and receive Automatic Dependent Surveillance (ADS) messages.

b. Verification of the AMSS Minimum Operational Performance Standards (MOPS) and related system performance requirements developed by the Radio Technical Commission for Aeronautics, SC-165.

Independent validation, verification, and assessment of the AMSS will be conducted in the FAA Technical Center Communications Test Facility (CTF). The CTF provides the facilities to collect sufficient data to verify that the AMSS system operates as specified in the AMSS SARPs and MOPS. A second source of validation will be obtained from the manufacturer's of the avionics equipment either through data obtained during system access approval and other testing, or certification letters stating compliance with SARPs requirements. Additional test and validation information is solicited from other states concerned with this activity.

1.2 PURPOSE.

The purpose of this document is to define the tests and experiments to be conducted by the FAA to independently validate and/or verify the SARPs and MOPS. Other planned testing by the FAA includes performance tests of the ADS system and of low data rate digitized voice communications systems used for Air Traffic Service (ATS).

1.3 BACKGROUND.

As part of the FAA effort to provide more efficient and effective communications, AMSS will initially be used to provide communications in areas of sparse coverage, primarily in oceanic Flight Information Regions (FIRs). Currently, aeronautical air-ground communication links are unreliable over much of the oceanic airspace due to the propagation characteristics of high frequency (HF) radio waves. AMSS will alleviate these deficiencies by providing voice and data communication services via satellite link.

AMSS will provide connectivity between aircraft and ground users using satellite and terrestrial networks. The initial service will provide reliable data communications for aircraft in oceanic airspace. Over land areas, AMSS will supplement other radio services in areas of sparse very high frequency (VHF) coverage.

Services to be provided by AMSS when fully operational will support ATS, Airline Operational Control (AOC), Airline Administrative Communications (AAC), and Aeronautical Passenger Communications (APC). An intended use for the initial one-way data service is ADS which provides updated position reports originated in the aircraft for ATS.

As part of the overall AMSS effort, the FAA plans to provide an assessment of the performance of the AMSS and ADS systems and present sufficient data to verify that the AMSS can provide communications for ATS and ADS functions. The FAA designed the CTF for this purpose. This work is not intended to preclude similar or complementary investigations in this area by other states.

1.4 APPROACH.

Several methods can be used to validate the SARPs. Six suggested validation methods are:

a. Inspection (I)
b. Analysis (A)
c. Simulation (S)
d. Demonstration (D)
e. Test (T)
f. Certification Letter (CL)

The CTF was developed to conduct the SARPs validation tests and demonstrations.

In developing the CTF, a careful review of existing AMSS documentation was conducted to ascertain the meaningful parameters that should be measured. The appropriate instrumentation was then selected for the measurement of these parameters.

The CTF will be used to validate the AMSS/ADS system/service functions; not to perform an exhaustive unit (black box) evaluation. The units which comprise the Aircraft Earth Station (AES) are being procured by the FAA and will be installed in the CTF. The CTF will not repeat the exhaustive tests required for unit validation; the CTF will measure those unit level parameters necessary to establish overall system performance.

1.5 RELATED DOCUMENTS.

a. Draft AMSS SARPs (Baseline), ICAO Montreal AMSSP SARPs Working Group (point of contact Pat Patak), September 1989.

b. Aeronautical System Definition Manual, Version 1.7, International Maritime Satellite Organization, 40 Melton Street, London, NW1 2EQ, England (point of contact Dr. G. Keith Smith).

c. ARINC Characteristic 741-1, Aviation Satellite Communication System, Aeronautical Radio, Inc.

d. ARINC Characteristic 429, Digital Information Transfer System, Aeronautical Radio, Inc.

2. COMMUNICATIONS TEST FACILITY.

2.1 FACILITY LOCATION.

The CTF is located in the Flight Operations Building at the FAA Technical Center, Atlantic City International Airport, New Jersey. Additional facilities required for link tests and end-to-end tests include the Comsat Ground Earth Station (GES) located in Southbury, Connecticut, and the ARINC Data Network Interface at the FAA Technical Center.

2.2 DESCRIPTION.

The CTF consists of a set of avionics to emulate an AES, a set of automated test equipment, and two computers interfaced to the avionics and test equipment to provide signal control and data acquisition functions. A functional diagram of the CTF equipment is provided in figure 1.

2.2.1 Test Equipment.

The test equipment includes a spectrum analyzer, power meter, frequency counter, vector modulation analyzer, vector generator, and signal generator, along with miscellaneous couplers, switches and attenuators. A brief description of the capabilities of the test equipment follows:

a. Spectrum Analyzer, Model HP 8566B. The spectrum analyzer is capable of generating frequency and amplitude plots in the range from 100 hertz (Hz) to 22 giga-hertz (GHz).

b. Microwave Power Meter, Model HP 438A. The power meter can measure radio frequency (RF) power up to a maximum frequency of 50 GHz.

c. Vector Signal Generator, Model HP 8780A. This unit is capable of generating phase and amplitude modulated signals up to a frequency of 3 GHz.

4. RF Signal Generator, Model HP 8673C. This unit is a capable of generating an RF signal up to 18 GHz.

5. Vector Modulation Analyzer, Model HP 8981A. This unit measures phase and amplitude of the modulated signal.

All of the microwave test equipment is controllable via the IEEE-488 General Purpose Interface Bus (GPIB) for remote operation. Other test equipment which will be required for testing various SARPs will be rented on a as needed basis.

In addition to the microwave test equipment, the following data communications test equipment also are part of the CTF.

a. Data Error Analyzer, Model 2000 "Firebird" (two each). These units are capable of measuring bit error rate (BER) on communications links.

b. Protocol Analyzer, Digilog Model 900. This unit performs testing and emulation of communications protocols.

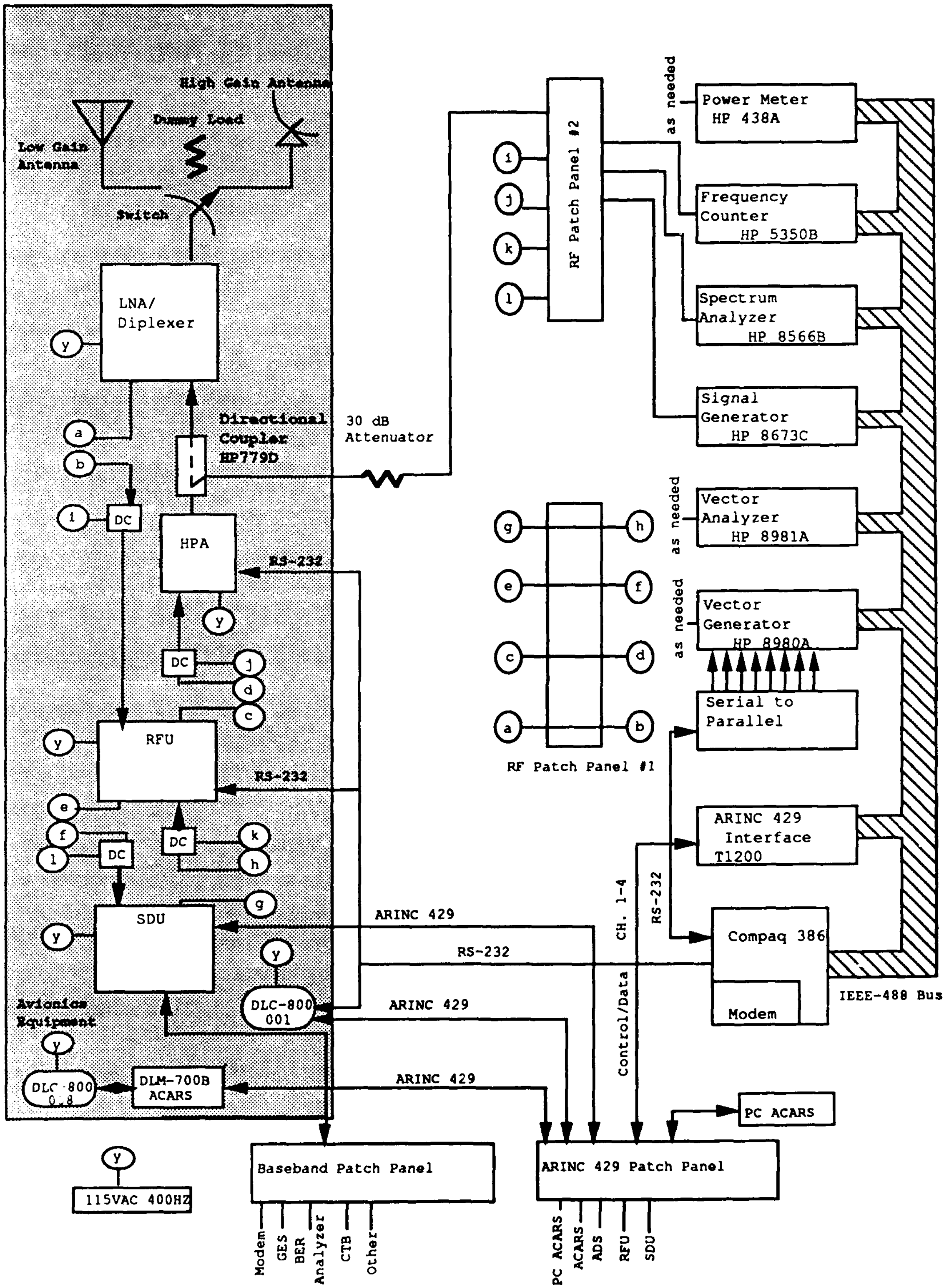


FIGURE 1. COMMUNICATIONS TEST FACILITY

c. ARINC 429 Test Set, JCAir Model T1200. This unit has four bidirectional ARINC 429 channels, two low speed and two high speed, all of which are controllable over the IEEE-488 bus. It will communicate with avionics, excluding Satellite Data Unit (SDU), using standard ARINC 429.

2.2.2 Avionics.

The initial avionics is capable of data communications at 600 bits per second (bps). As higher data rate capable avionics are made available, the CTF will be upgraded to allow tests of higher data rates and voice communications. The avionics components include:

a. SDU. The SDU performs all protocol functions, forward error correction and modulation/demodulation. The protocol functions may be bypassed through a data test port, which provides direct access to the circuitry that performs the forward error correction and modulation/demodulation. Initially, the SDU will support data transmission at 600 bps. It will be upgraded to provide higher data rates and digitized voice communications.

b. Radio Frequency Unit (RFU). The RFU performs up and down conversion between L-Band and intermediate frequency (IF) frequencies. It is controlled by the SDU over an ARINC 429 interface.

c. High Power Amplifier (HPA). The HPA supports RF transmission in the L-Band using a Class C amplifier. The output is controllable from 0 to 16 decibel referred to one watt in 1 decibel (dBW) steps through an internal attenuator over the ARINC 429 interface. Later validation tests will require the use of a Class A (linear) amplifier.

d. Low Noise Amplifier/Diplexer (LNA). The LNA isolates the transmit power from the receive signal path and amplifies the low level RF received signals.

e. Low Gain Antenna. The low gain antenna is omnidirectional and designed for a minimum gain of 0 decibel relative to isotropic (dBi).

6. High Gain Antenna. A commercially available high gain antenna having a minimum gain of 20 dBi has been procured for end-to-end system tests.

2.2.3 Computer Control and Software.

The avionics installed in the CTF is controlled by a Data Link Control unit (DLC-800) manufactured by Rockwell Collins. This will provide direct control of the avionics allowing the COMPAQ 386 computer to be used strictly for operating test equipment and test data recording. Another computer will be equipped with a Pacific Avionics Arinc 429 card which will allow the CTF to emulate "Williamsburg" 429 Protocol from software developed using the "C" language. This will provide the ability to send test messages through the SDU.

The software that will be used to support the operation of the CTF will be developed using the ASYST 3.0 data acquisition and analysis package. ASYST is an interpreted software development and environment based on the programming language FORTH.

The ASYST language was selected because of its extensive capabilities in data acquisition and analysis and its GPIB control functions.

ASYST programs will be used primarily for tests which require repetitive measurements and/or extensive analysis and data reduction.

2.3 GROUND EARTH STATION.

The GES, located in Southbury, Connecticut, supports AMSS protocols and services. The GES also records billing information, and interfaces with the ARINC Data Network Services (ADNS) front-end processor. The front-end processor converts the AMSS messages to the proper format for routing on the ADNS network.

Future plans require the installation of additional equipment at the Communications Satellite Corporation (COMSAT) earth station such as, an ABPSK modem, a computer, and test instrumentation. The modem will interface to the GES at IF frequencies and can be operated using software which emulates the AMSS protocols. An overview of the end-to-end test configuration is shown in figure 2.

2.4 CALIBRATION.

All test equipment will be calibrated using standards traceable to the National Institute of Technology and Standards. The calibration will be handled through FAA administrative channels and will be repeated periodically. The calibration records will be kept with the equipment.

3. TEST PROGRAM DESCRIPTION.

3.1 PROGRAM DESCRIPTION.

The tests conducted will be used to validate the parameters specified in the AMSS SARPs and to provide the data required to assess system performance. A given SARPs requirement will be considered validated if equipment satisfying the requirement provides adequate AMSS system performance. The BER will be used as a measure of adequate system performance. The test program is divided into four phases.

a. Phase I tests will verify the proper function of test equipment and test software.

b. Phase II tests will verify the operation and performance of the avionics without RF propagation.

c. Phase III tests will verify the SARPs requirements related to the signal-in-space and satellite link performance.

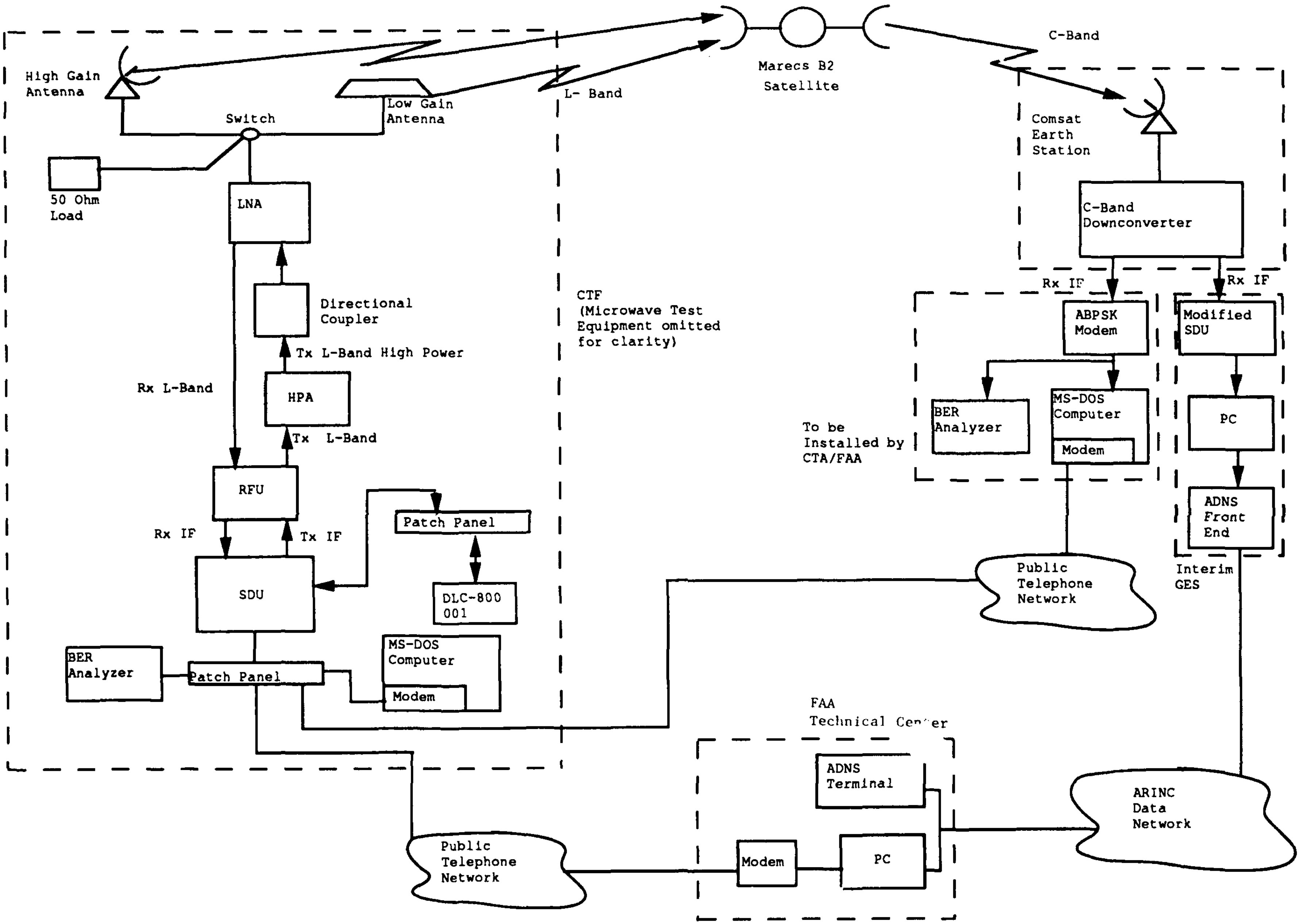


FIGURE 2. END-TO-END TEST CONFIGURATION OVERVIEW

d. Phase IV tests will evaluate end-to-end system performance. The end-to-end functions include, but are not limited to, ADS and digitized voice communications.

AMSS protocols will be evaluated as a separate task using simulation routines. The simulations will test the protocols defined in the SARPs for their functionality and effect on channel loading. The results of the simulations will determine specific protocol tests to be conducted in the CTF.

A brief list of the tests to be conducted in each phase is provided in sections 3.1.1 through 3.1.4. A SARPs Validation Test Matrix indicating the method of verification is provided in appendix A. Validation or verification by analysis may include the review of previous test data and manufacturer supplied data and/or certification letters. Appendix B contains a description of the tests that will be conducted in the CTF to validate the ICAO AMSS SARPs. The descriptions include the test configuration, data to be recorded, performance criteria, and SARPs requirement verified.

3.1.1 Phase I Tests.

These tests will verify that the test equipment is correctly interfaced to the IEEE-488 and ARINC 429 buses. Phase I tests include, but are not limited to:

a. Test I-1: ASYST Software Control of Test Equipment.

b. Test I-2: ASYST Software Control of ARINC 429 Interface.

c. Test I-3: Performance Verification of Directional Coupler.

d. Test I-4: Insertion Loss Measurements of Test Access Points.

e. Test I-5: Insertion Loss Measurements of Long Cable Runs.

f. Test I-6: Return Loss Measurements from HPA output to antennas.

3.1.2 Phase II Tests.

These tests will verify the operation and performance of the avionics in a laboratory setting without using a satellite link. The tests are conducted by terminating the transmitter RF output into a 50 ohm load. Avionics performance capabilities will be measured to establish a baseline. Phase II tests include, but are not limited to:

a. Test II-1: Spectral Analysis.

b. Test II-2: Third Order Intermodulation Products.

c. Test II-3: Power Measurements.

d. Test II-4: Transmit Phase Noise Measurement.

e. Test II-5: Transmit Frequency Measurements.

3.1.3 Phase III Tests.

These tests will be conducted over a satellite link. Some RF parameter tests will be repeated to validate them under actual operating conditions. The Phase III tests include the verification of link and network protocols. The protocols will be validated under operational conditions (i.e., over the satellite link) after the functional protocols tests using simulations are complete. Phase III tests include, but are not limited to:

a. Test III-1: Transmit/Received Spectrum Analysis.

b. Test III-2: Received Phase Noise Measurements.

c. Test III-3: Demodulator Performance.

d. Test III-4: Channel Performance vs Power.

e. Test III-5: Received Signal Measurements.

3.1.4 Phase IV Tests.

Phase IV tests are end-to-end system level performance tests. They will require the use of the CTF, satellite link, and a terrestrial network. Phase IV tests being planned at this time include, but are not limited to:

a. Test IV-1: ADS Message Time Delay.

b. Test IV-2: Low Data Rate Voice Coder/Decoder (CODEC) Evaluation.

3.2 DATA REDUCTION AND ANALYSIS.

Test data will be collected by the COMPAQ 386 computer and will be reduced to a form which will allow for comparison with SARPs requirements by the ASYST software. The data will be analyzed to determine the SARPs requirement has been satisfied.

3.3 TEST REPORTS.

At the end of each test phase a test report will be prepared which will contain the results of all tests performed. If necessary for AMSS system performance, a recommendation to change a given SARPs requirement will be made.

4. SCHEDULE.

Phases I through III tests are planned to be completed in one calendar year with an anticipated start date in the second quarter of 1991. A detailed schedule will be supplied at a later date.

5. AREAS OF RESPONSIBILITY.

ACD-330: Responsible for all Technical Center activities. Will monitor SARPs tests, ADS tests, and conduct flight tests. Will be responsible for obtaining

FCC licenses and coordinating the Memoranda of Agreement between the FAA and other organizations.

ARD-300: Responsible for program management and funding for satellite communications projects. Will provide the U.S. ICAO member to the AMSS panel and the representative to the RTCA committees.

CTA: Responsible to ACD-330 in SARPs testing activities. Will provide test engineering services, develop test plans, conduct tests, perform data analysis, and provide test reports.

COMSAT: Responsible for obtaining free use of INMARSAT space segment and for providing FAA access to the GES for testing.

CTF SCHEDULE

Install Test Equipment in Racks	8/90
Receive Avionics	9/90
Install Avionics	9/90
Install NEMA Enclosure on Roof	9/90
Draft Test Procedures Document	4/91
MOU with COMSAT	7/90
Begin Phase I Tests	5/91
Phase I Test Report Draft	6/91
Begin Phase II Tests	7/91
Phase II Test Report Draft	8/91
Begin Phase III Tests	Schedule TBD pending the availability of voice capable avionics.
Phase III Test Report Draft	

APPENDIX A

SARPs VALIDATION TEST MATRIX

Appendix A contains an AMSS SARPs Validation Cross-Reference Matrix allowing for the tracking of SARPs requirements and recommendations as well as the proposed method validation to be utilized for these requirements. At present there are five methods of validation:

1. Inspection (I)	Verify by physical inspection
2. Analysis (A)	Verify by analysis of the manufacturer's/ service provider's test data and software audits
3. Simulation (S)	Verify by simulation/emulation of system and/or simulation of performance and protocols
4. Demonstration (D)	Verify that capability exists
5. Test (T)	Verify by component or system testing
6. Certification Letter (CL)	Certification Letter from avionics manufacturer stating compliance with SARPs (Parameters requiring a certification letter are under review)

AMSS SARPs VALIDATION CROSS-REFERENCE MATRIX

SARPs Paragraph Number	Validation Method Requirement	N/A	I	A	S	D	T	CL
1.	Definitions and System Capabilities	X						
1.1	Channel Types	X						
1.1.1	P-Channel	X						
1.1.2	R-Channel	X						
1.1.3	T-Channel	X						
1.1.4	C-Channel	X						
1.2	System Capabilities	X						
1.2.1	Level 1	X						
1.2.1.1	[Level 1 Requirement]					X		
1.2.1.2	[P-Channel Requirement]					X		
2.	Broadband RF Characteristics	X						
2.1	Frequency Bands	X						
2.1.1	Use of AMS(R)S Bands	X						
2.1.1.1	[Priority of AMS(R)S messages Part 2/5.1.8]						X	
2.1.2	To Aircraft	X						
2.1.2.1	[Receive in 1544-1555 MHz Band]					X		
2.1.2.2	[Receive in 1555-1559 MHz Band]					X		
2.1.2.3	[Receive in 1530-1544 MHz Band]					X		
2.1.3	From Aircraft	X						
2.1.3.1	[Transmit in 1645.5-1656.5 MHz Band]					X		
2.1.3.2	[Transmit in 1656.5-1660.5 MHz Band]					X		
2.1.3.3	[Transmit in 1626.5-1645.5 MHz Band]					X		
2.1.4	Tuning Increments	X						
2.1.4.1	[2.5 kHz tuning increments]					X		
2.1.4.2	[Channel assignment/tuning control]					X		
2.1.5	Channel Numbering	X						
2.1.5.1	[C_{υ} Channel number]	X				X		
2.1.5.2	[C_{ς} Channel number]	X				X		
2.2	Frequency accuracy and compensation	X						
2.2.1	Aircraft Earth Station	X						
2.2.1.1	[Doppler Correction]			X		X		
2.2.2	GES [Aeronautical Earth Station]	X						
2.2.2.1	[GES Frequency compensation]			X		X		
2.3	Reserved Channels	X						
2.3.1	[Manual control of reserved channels]						X	
2.4	Aircraft Earth Stations	X						

AMSS SARPs VALIDATION CROSS-REFERENCE MATRIX (CONTINUED)

SARPs Paragraph Number	Validation Method Requirement	N/A	I	A	S	D	T	CL
2.4.1	General Antenna Characteristics	X						
2.4.1.2	Reference Coverage Volume			X				
2.4.1.2.1	[Recommended Coverage Volume]			X		X		
2.4.1.3	Axial Ratio			X				
2.4.1.4	Polarization			X				
2.4.1.5	Antenna Switching			X		X		
2.4.2	Low Gain Antenna Subsystems	X						
2.4.2.1	Gain			X				
2.4.3	High Gain Antenna Subsystems	X						
2.4.3.1	Gain			X				
2.4.3.2	Discrimination			X				
2.4.3.3	Antenna Boresight Steering	X						
2.4.3.3.1	Antenna Orientation			X				
2.4.3.4	Satellite Acquisition			X		X		
2.4.3.5	Phase Discontinuity			X				
2.4.4	Receiver Requirements	X						
2.4.4.1	Gain-to-Noise Temperature Ratio			X				
2.4.4.2	Dynamic Range			X		X		
2.4.4.3	Received Phase Noise			X			X	
2.4.5	Transmitter Requirements	X						
2.4.5.1	EIRP Limits			X		X		
2.4.5.2	EIRP Controls			X		X		
2.4.5.3	Carrier Off Level			X			X	
2.4.5.4	Spurious Outputs			X			X	
2.4.5.4.1	[Spurious Outputs/harmful Interference]			X				
2.4.5.5	Harmonic Outputs			X		X		
2.4.5.6	Intermodulation Products			X		X		
2.4.5.7	Phase Noise			X			X	
2.4.5.8	Power Stability			X			X	
3.	RF Channel Characteristics	X						
3.1	Modulation Method	X						
3.1.1	For Data Rates 2.4 Kbits/s and below	X						
3.1.1.1	[A-BPSK Modulation]			X		X		
3.1.1.2	[Pulse-shaping filters]			X		X		
3.1.2	For Data Rates Above 2.4 Kbit/s	X						
3.1.2.1	[A-QPSK Modulation]			X		X		
3.2	Bounds on Radiation Power Spectral Density	X						
3.2.1	From Aircraft			X		X		
3.2.2	To Aircraft			X				

AMSS SARPs VALIDIATION CROSS-REFERENCE MATRIX (CONTINUED)

	Validation Method							
SARPs Paragraph Number	Requirement	N/A	I	A	S	D	T	CL
3.3	Demodulation Performance			X		X		
4.	Channel Format Types and Rates	X						
4.1	General							
4.1.1	Aircraft System-Timing Reference Point			X				
4.1.2	Channel Bit Rates			X		X		
4.2	P-Channel	X						
4.2.1	Data Clock Accuracy			X				
4.2.2	Frame Format	X						
4.2.2.1	General Characteristics			X		X		
4.2.2.2	Format Identifier			X		X		
4.2.2.3	Superframe Boundary Marker			X		X		
4.2.2.4	Dummy Field			X		X		
4.2.2.5	Information Field			X		X		
4.2.2.5.1	Scrambling			X		X		
4.2.2.5.2	Forward Error Correction (FEC) Coding			X		X		
4.2.2.5.3	Interleaving			X		X		
4.2.2.6	Unique Word			X		X		
4.2.3	Performance			X		X		
4.3	R-Channel	X						
4.3.1	Data Clock Accuracy			X				
4.3.2	Burst Timing			X				
4.3.3	Burst Format	X						
4.3.3.1	General Characteristics			X		X		
4.3.3.2	Preamble			X		X		
4.3.3.3	Unique Word			X		X		
4.3.3.4	Information Field			X		X		
4.3.3.4.1	Scrambling			X		X		
4.3.3.4.2	Forward Error Correction (FEC) Coding			X		X		
4.3.3.4.3	Interleaving			X		X		
4.3.4	Performance			X		X		
4.4	T-Channel	X						
4.4.1	Data Clock Accuracy			X				
4.4.2	Timing Relative to P-Channel			X		X		
4.4.3	Burst Structure	X						
4.4.3.1	General Characteristics			X		X		
4.4.3.2	Preamble			X		X		
4.4.3.3	Unique Word			X		X		
4.4.3.4.1	Scrambling			X		X		
4.4.3.4.2	Forward Error Correction (FEC) Coding			X		X		

AMSS SARPs VALIDATION CROSS-REFERENCE MATRIX (CONTINUED)

SARPs Paragraph Number	Requirement	N/A	I	A	S	D	T	CL
	Validation Method							
4.4.3.4.3	Interleaving			X		X		
4.4.4	Performance			X		X		
4.5	C-Channel	X						
4.5.1	Data Clock Accuracy			X				
4.5.2	Transmission Formats	X						
4.5.2.1	To Aircraft			X		X		
4.5.2.2	Preamble			X		X		
4.5.2.3	From Aircraft	X						
4.5.3	Frame Format	X						
4.5.3.1	Unique Word			X		X		
4.5.3.2	Dummy Field	X						
4.5.3.3	Information Field	X						
4.5.3.3.1	Information Field Structure Including Sub-band data Field			X		X		
4.5.3.3.2	Scrambling			X		X		
4.5.3.3.3	Forward Error Correction (FEC) Coding			X		X		
4.5.3.3.4	Interleaving			X		X		
4.5.4	Performance	X						
4.6	Other Channels (TBD)	X						
5.X – 10.X	To Be Supplied							

APPENDIX B

SARPs TEST DESCRIPTION

TEST II-I: SPECTRAL ANALYSIS.

PURPOSE.

1. Validate the transmit spectrum requirements defined in SARPs for the aircraft earth station direct measurement.

TEST CONFIGURATION.

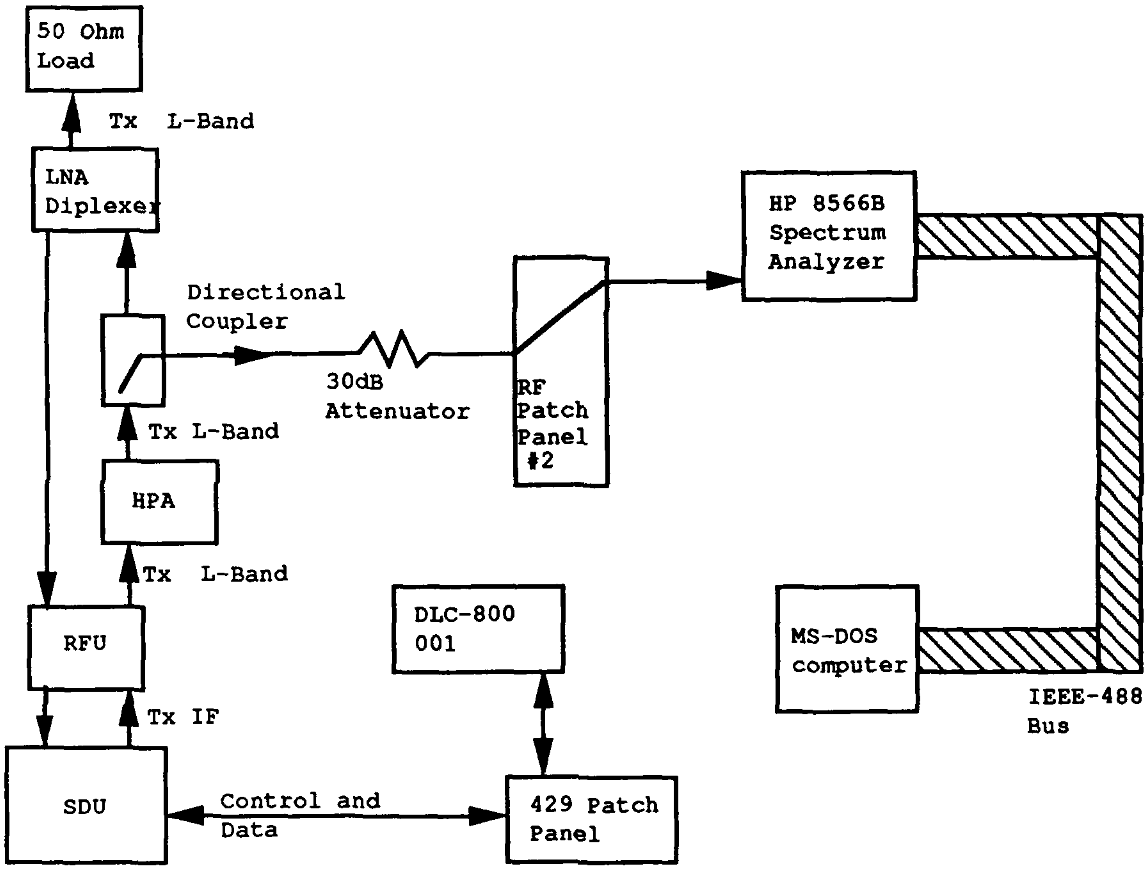


FIGURE II-1. SPECTRAL ANALYSIS TEST ANALYSIS

TEST METHOD.

The avionics operate in a continuous transmit mode with the antenna port terminated in a 50 ohm load. The transmit spectrum is measured directly using the HP 8566B Spectrum Analyzer. Measurements are taken for HPA attenuator settings of 16 dB, 8 dB, and 0 dB and at the highest, lowest, and middle frequencies in the transmit mode.

DATA RECORDED:

Spectrum analysis consists of three sets of measurements.

1. Spurious Outputs. Amplitude measurements of spurious emanations, if any, are taken using a 10 kHz resolution bandwidth at frequencies starting from 10 kHz on both sides of the carrier.

2. Harmonic Outputs. Amplitudes of carrier harmonics are measured to a frequency of 18 GHz.

3. Power Spectrum. The total power output spectrum is measured for a frequency span of +/- 4 times the data rate, centered at the carrier.

CRITERIA.

SARPs criteria for the above listed items are presented below.

1. Spurious Outputs. At all times when transmitting a continuous unmodulated carrier at any level up to the maximum power, the composite spurious and noise output EIRP (excluding harmonics but including phase noise) generated by the aircraft earth station when measured to the carrier EIRP shall not exceed in a 4 kHz band:

Frequency (MHz)	EIRP
below 1559	-83 dBc
above 1559	-55 dBc

(Note 1: In the band 1530 to 1559 MHz, the level of spurious signals should be -83 dBc or less.)

(Note 2: Excluding the frequency band of +/- 10 kHz on either side of the carrier.)

2. Harmonic Outputs. The EIRP of any radiated harmonic shall be less than -38 dBW for any frequency up to 18 GHz.

3. Power Spectrum. The power spectrum radiated by the aircraft is to be within the bounds indicated in figure II-1.1.

REQUIREMENT:

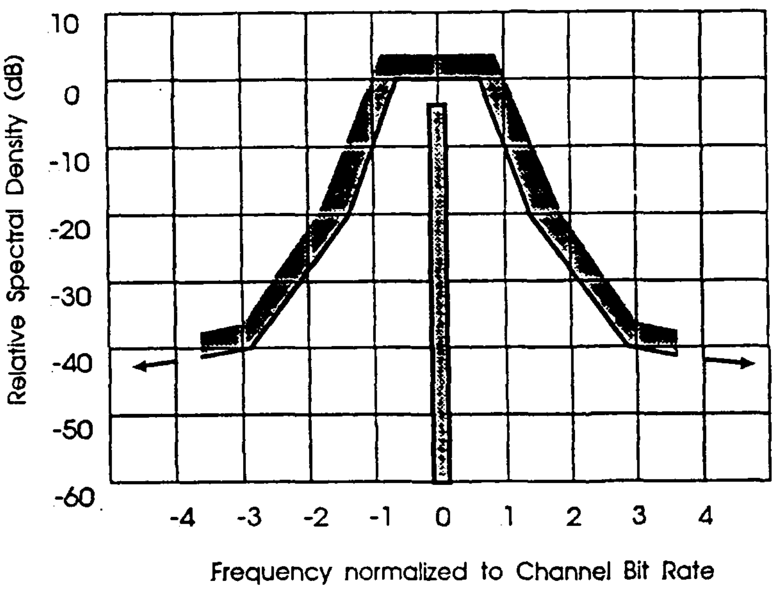
SARPs requirements validated by this test and by successful completion of the channel performance test (Test III-4) are:

1. Spurious Outputs. SARPs requirement 2.4.5.4.

2. Harmonic Outputs. SARPs requirement 2.4.5.5.

3. Transmit Power Spectrum. SARPs requirement 3.2.1.

Figure 3.6a AES A-BPSK Transmit Spectrum Mask



Frequency Offset (normalized to channel bit rate)	Relative Spectral Density (dB)
-35 kHz[1]	-55 dBc/4kHz
-2.8	-40
-1.4	-20
-0.625	0
-0.1	-3
0.1	-3
0.625	0
1.4	-20
2.8	-40
35 kHz	-55 dBc/4kHz

Note 1. At +/- 35 kHz the spurious output measured in a 4 kHz band shall be at least 55 dB below the unmodulated carrier level. For larger frequency offsets, the spurious requirements for unmodulated carriers shall apply.

FIGURE II-1.1. RADIATED POWER SPECTRAL DENSITY NORMALIZED TO CHANNEL BIT RATE

TEST II-2: THIRD ORDER INTERMODULATION DISTORTION.

PURPOSE.

To validate Third Order Intermodulation products requirements defined by SARPs for aircraft earth station with linear high power amplifiers by direct measurement.

TEST CONFIGURATION.

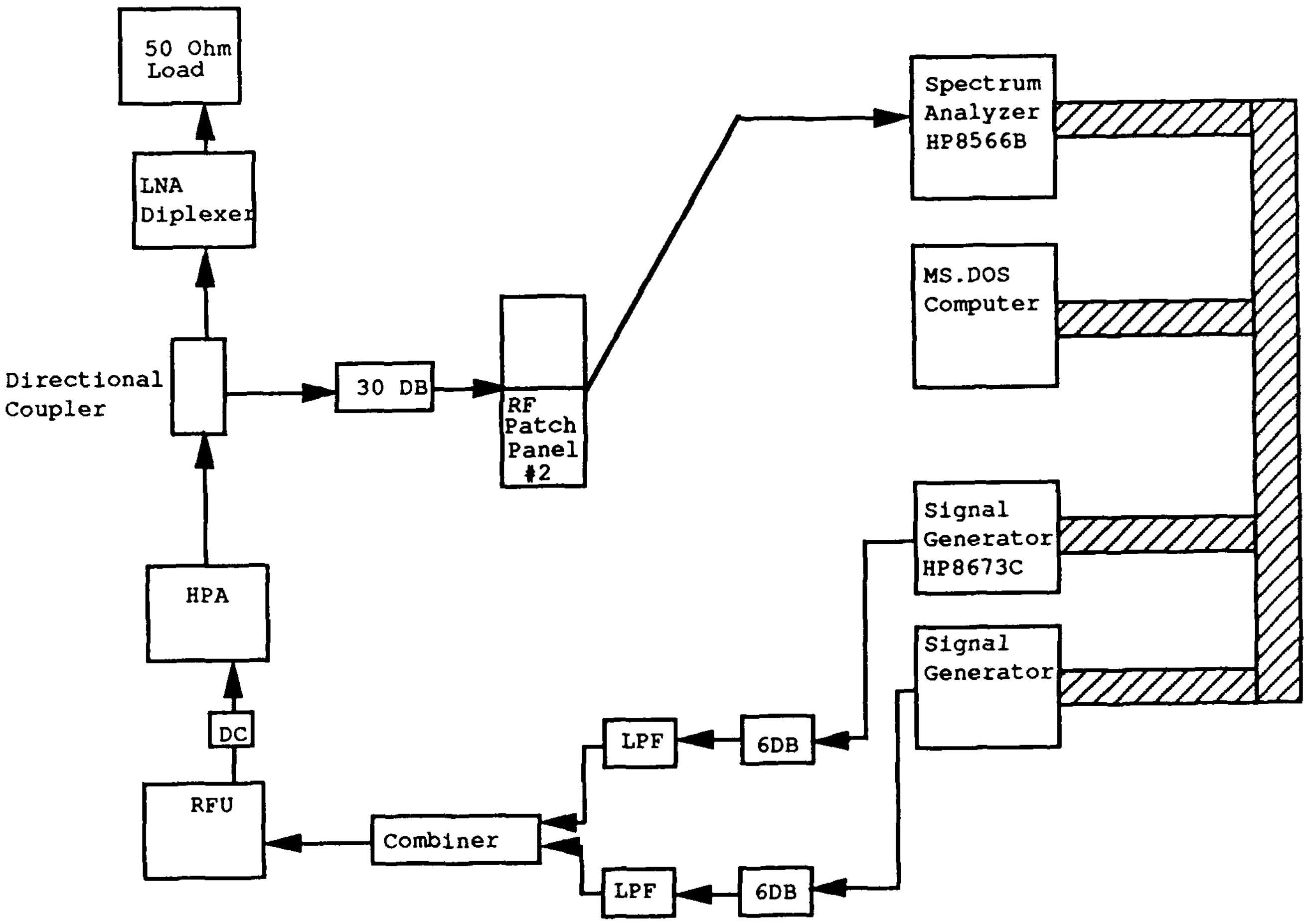


FIGURE II-2. THIRD ORDER INTERMODULATION DISTORTION TEST ANALYSIS

TEST METHOD.

The avionics will operate in a transmit mode with the antenna port feeding into the spectrum analyzer. Two signal generators will provide dual IF carriers into the RFU at the low, middle, and high end of the transmit IF range.

DATA RECORDED.

Third Order Intermodulation Distortion will be measured with 10 kHz resolution bandwidth with frequencies starting from 10 kHz of the two carriers.

CRITERIA.

SARPs Criteria for the above item is presented below.

1. Intermodulation products. The EIRP of any intermodulation product shall be less than [ ] dBW.

(Note: For aircraft stations employing linear amplifiers when the transmitter is driven by two equal carriers each producing output power of 10.5 dbW at the input to the antenna, the individual third order IMD products shall not exceed [14.5 dbW] at the input to the antenna.)

Further reduction is expected from operational actions including optimization of AES antenna beam pointing, channel assignment within the spectrum, satellite spacing, and EIRP control.

REQUIREMENT.

SARPs validated by this test:

1. Intermodulation Products. SARPs requirement 2.4.5.6.

TEST II-3: POWER MEASUREMENTS.

PURPOSE.

1. Validate the power requirements defined in SARPs for the aircraft earth station by direct measurement operating the avionics into a dummy load.

2. Verify the power output capability of the avionics.

TEST CONFIGURATION.

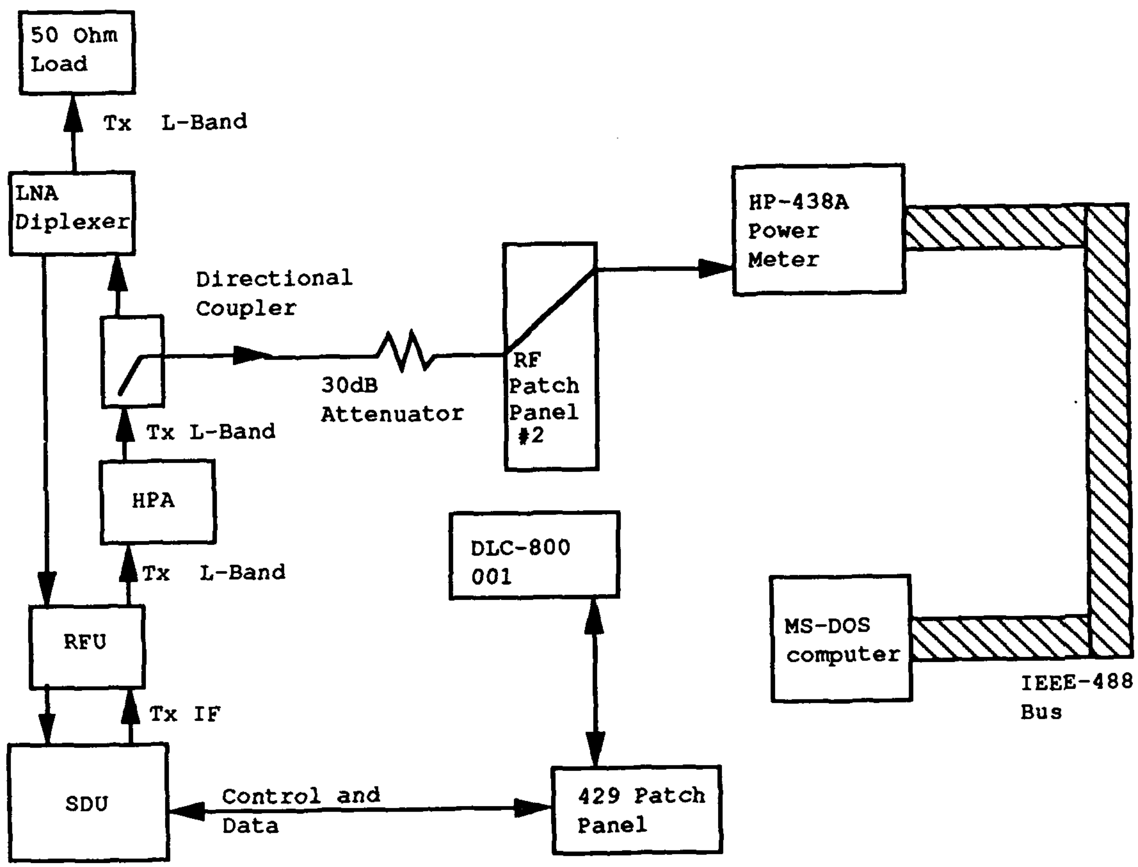


FIGURE II-3. POWER MEASUREMENTS TEST ANALYSIS

TEST METHOD.

The avionics operate in continuous transmit mode with the antenna port terminated into a 50 ohm load. The power output is measured using the HP 438A Power Meter through a directional coupler at the antenna port and 30 dB of attenuation. Measurements are taken for HPA attenuator settings of 16 dB, 8 dB, and 0 dB at the highest, lowest, and middle frequencies in the transmit mode.

DATA RECORDED.

Power measurements consist of two items:

1. Power Stability. The output power of the AES is measured periodically.

2. Carrier Off Level. Measurements of the power emitted by the AES, when it is not transmitting, a carrier is made.

CRITERIA.

SARPs criteria for the above listed items are presented below.

1. Power Stability. The AES must maintain the commanded output power of the carrier to within +/- 1 dB.

2. Carrier Off Level. The total power emitted by the AES when not transmitting a carrier shall be no more than -24 dBW.

REQUIREMENT.

SARPs requirements validated by this test and by successful completion of the channel performance test (Test III-4) are:

1. Power Stability. SARPs requirement 2.4.5.8.

2. Carrier Off Level. SARPs requirement 2.4.5.3.

TEST II-4: TRANSMIT PHASE NOISE MEASUREMENTS.

PURPOSE.

1. Validate the phase noise requirements defined in SARPs for the aircraft earth station by direct measurement.

TEST CONFIGURATION.

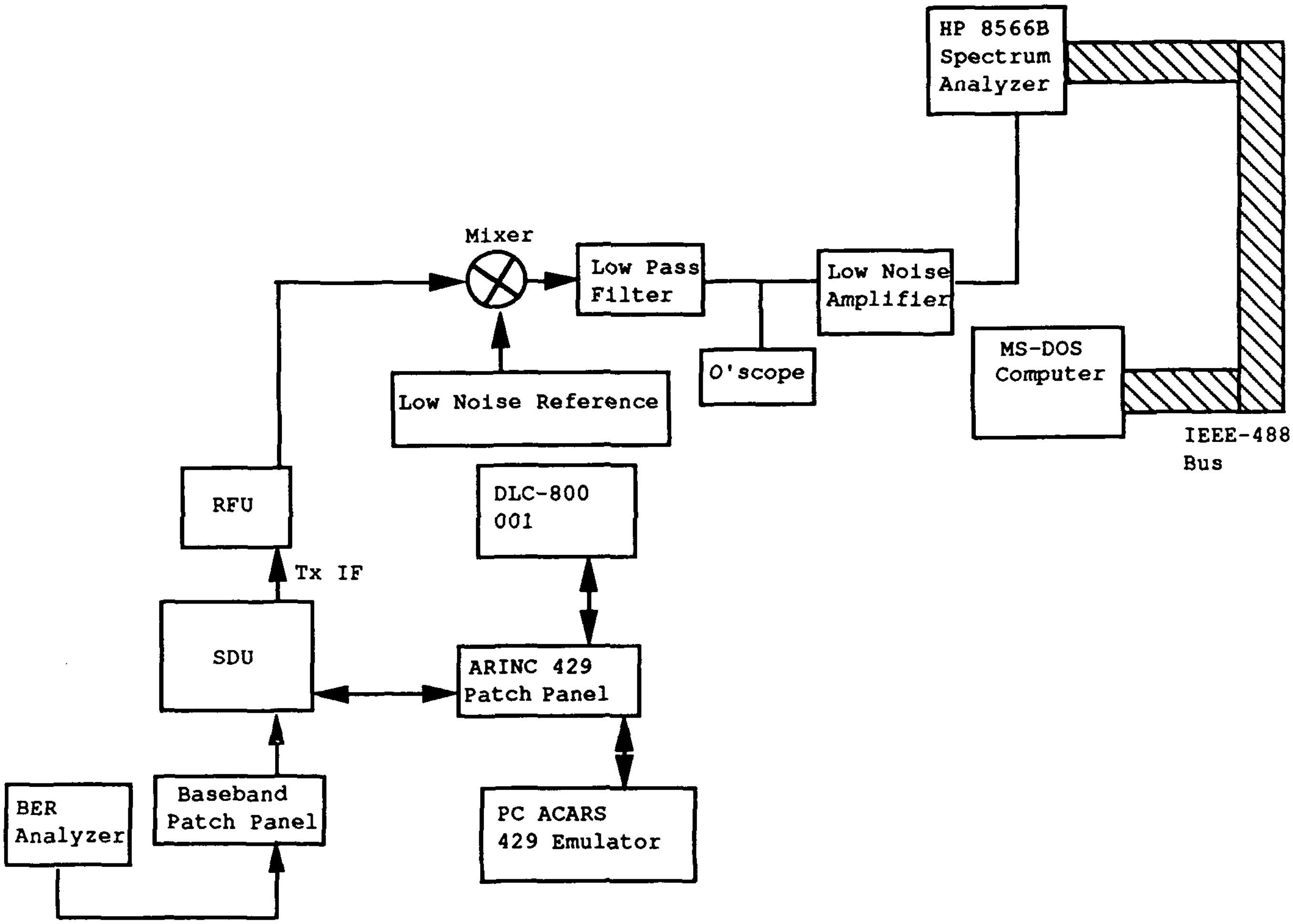


FIGURE II-4. TRANSMIT PHASE NOISE MEASUREMENT TEST ANALYSIS

TEST METHOD.

The avionics operate in a continuous transmit mode. The phase noise is measured by taking RFU output directly into an L-Band Mixer which has a second input from a Low Noise Reference source. The mixer output is applied to a Low Pass Filter whose output is monitored by an oscilloscope. The filter output is applied to a Low Noise Amplifier and measured on a spectrum analyzer.

DATA RECORDED.

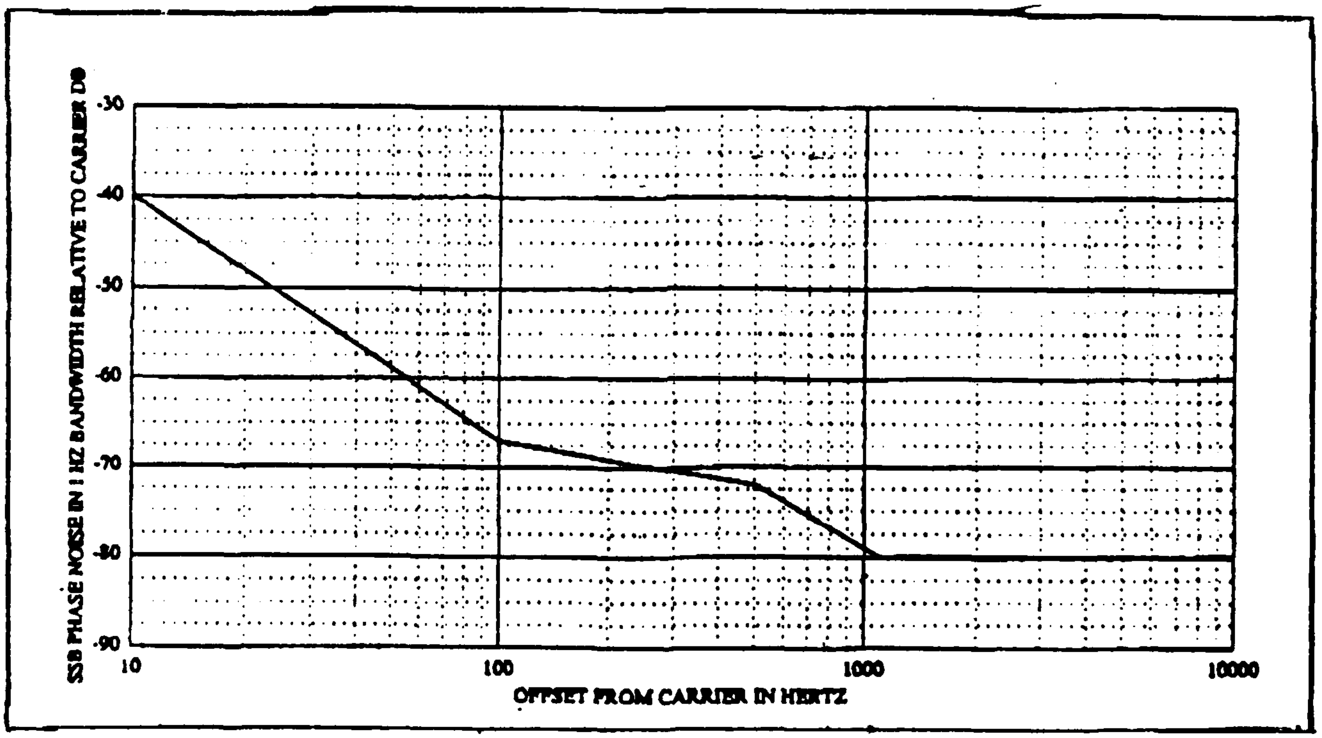
Phase noise power spectral density measured on the modulated carrier using the HP 8566B Spectrum Analyzer.

CRITERIA.

The phase noise induced on a modulated carrier must not exceed the power density given in SARPs figure II-4.

REQUIREMENT.

SARPs requirement 2.4.5.7 is validated by this test.



TEST II-5. TRANSMIT FREQUENCY MEASUREMENTS.

PURPOSE.

1. Verify that the transmit frequency of the avionics meets the tolerance requirements defined in the SARPs for the aircraft earth station.

2. Verify that the avionics are capable of tuning the transmit frequency in the steps required by SARPs.

TEST CONFIGURATION.

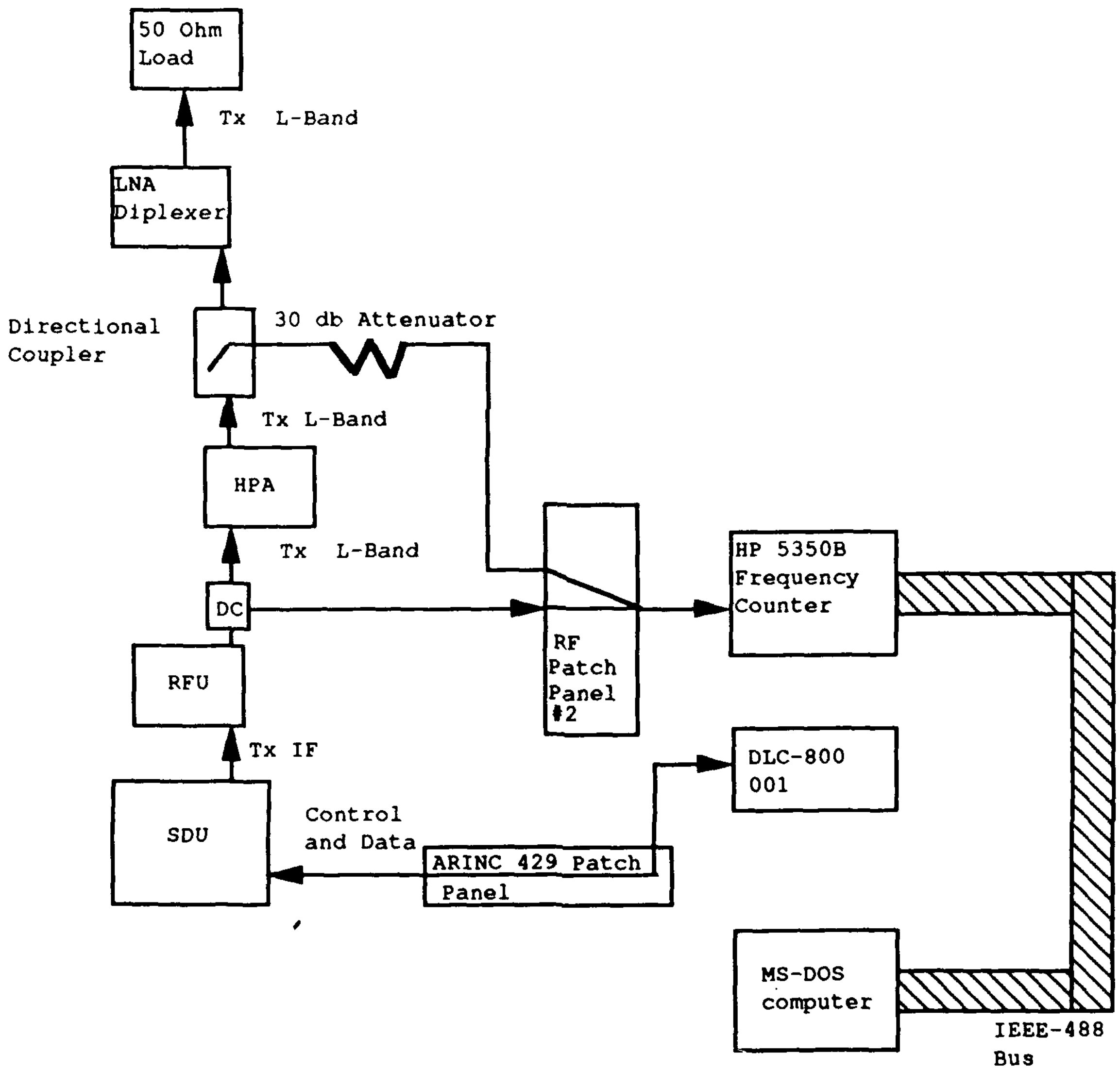


FIGURE II-5. TRANSMIT FREQUENCY MEASUREMENTS TEST ANALYSIS

TEST METHOD.

The transmit frequency of the avionics is measured and any deviations are recorded. The difference between adjacent commanded frequencies in the RFU is measured. Tuning across the entire range of the transmit frequency bands will be recorded.

DATA RECORDED.

Expected frequency and actual frequency of the transmit L-Band signal, prior to and after being amplified by the HPA, is recorded. The difference is calculated and recorded.

CRITERIA.

1. The frequency of the transmission from the aircraft earth station shall not vary from the nominal channel frequency by more than 350 Hz.

2. The channels are allocated throughout the band in increments of 2.5 kHz.

REQUIREMENT.

1. Transmission Frequency Accuracy: SARPs requirement 2.2.1.1.

2. Tuning Increments: SARPs requirement 2.1.4.1.

3. Transmit Frequency Bands. SARPs requirements 2.1.3.1 to 2.1.3.3.

TEST III-1: TRANSMIT/RECEIVED SPECTRUM ANALYSIS.

PURPOSE.

1. Validate the spectrum requirements defined in SARPs for the aircraft earth station by direct measurement while monitoring RF channel performance.

TEST CONFIGURATION.

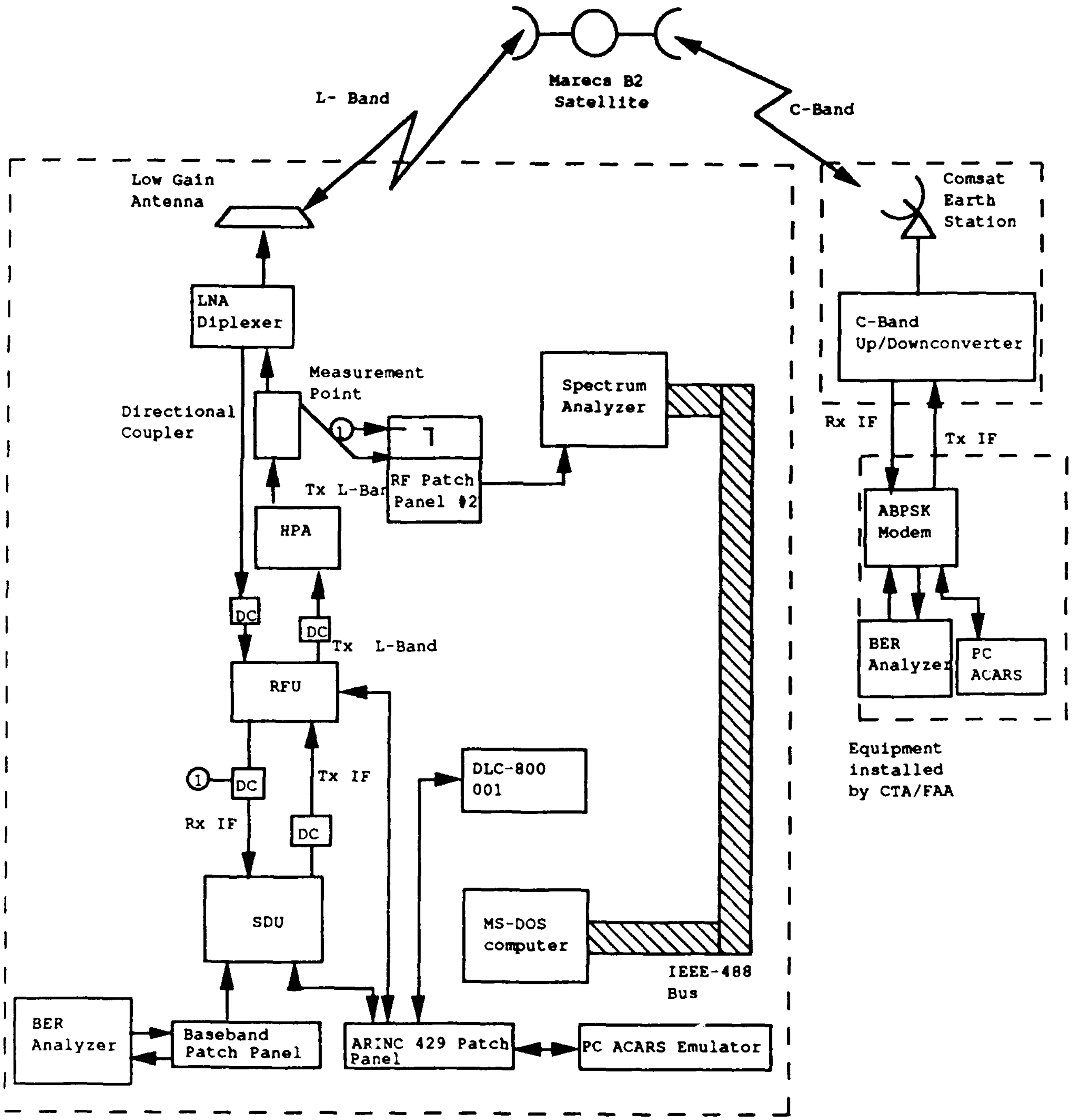


FIGURE III-1. TRANSMIT/RECEIVED SPECTRUM ANALYSIS TEST ANALYSIS

TEST METHOD.

The avionics operate in continuous transmit mode. The transmit spectrum is measured directly at the antenna port using the HP 8566B Spectrum Analyzer. Measurements are taken for HPA attenuator settings of 16 dB, 8dB, and 0 dB and are recommended at the highest, lowest, and middle frequencies in the transmit band. The actual frequencies for testing is determined by MOA with COMSAT.

DATA RECORDED.

Spectrum analysis consists of three measurement sets.

1. Spurious Outputs. Amplitude measurements of spurious emanations, if any, are taken using a 10 kHz resolution bandwidth at frequencies starting from 10 kHz above and below the carrier.

2. Harmonic Outputs. Amplitude of carrier harmonic no greater than 18G Hz will be measured.

3. Power Spectrum. The total power output spectrum is measured over a frequency span of +/- 4 times the data rate centered at the transmit or receive carrier frequency.

4. Bit Error Rate (BER). BER is measured in order to verify system performance, using an error analyzer at the ground earth station. An operator at the earth station records the data.

CRITERIA.

SARPs criteria for the above listed items are presented below.

1. Spurious Outputs. At all times when transmitting a continuous unmodulated carrier at any level up to the maximum power, the composite spurious and noise output EIRP (excluding harmonics but including phase noise) transmitted by the aircraft earth station when measured relative to the carrier EIRP must not exceed in a 4 kHz band:

Frequency (MHz)	EIRP
below 1559	-83 dBc
above 1559	-55 dBc

(Note 1: In the band 1530 to 1559 MHz, the level of spurious signals should be -83 dBc or less).

(Note 2: Excluding the frequency band of +/- 10 kHz on either side of the carrier.)

2. Harmonic Outputs. The EIRP of any radiated harmonic must be less than -38 dBW for any frequency up to 18 GHz.

3. Power Spectrum. The power spectrum radiated by the aircraft must fall within the bounds indicated in SARPs figure III-1.1.

4. Channel Performance. The overall physical layer is configured such that the average bit error rate is 10^{-5} or less after forward error correction.

REQUIREMENT.

SARPs requirements validated by this test are:

1. Spurious Outputs. SARPs requirement 2.4.5.4.

2. Harmonic Outputs. SARPs requirement 2.3.5.5.

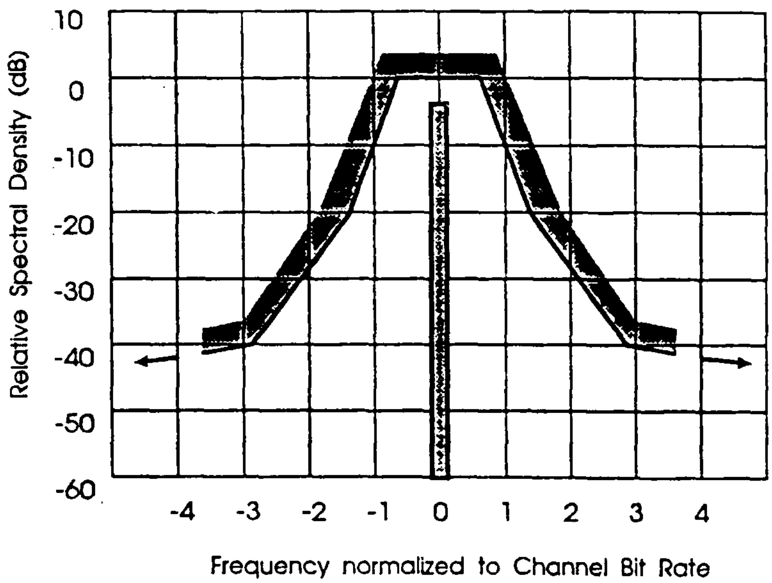
3. A-BPSK Modulation. SARPs requirement 3.1.1.1.

4. A-QPSK Modulation. SARPs requirement 3.1.2.1.

5. Transmit Power Spectrum. SARPs requirement 3.2.1.

6. Bit Error Rate. SARPs requirement 4.4.4.

AES A-BPSK Transmit Spectrum Mask



Frequency Offset (normalized to channel bit rate)	Relative Spectral Density (dB)
-35 kHz[1]	-55 dBc/4kH-
-2.8	-40
-1.4	-20
-0.625	0
-0.1	-3
0.1	-3
0.625	0
1.4	-20
2.8	-40
35 kHz	-55 dBc/4kHz

Note 1. At +/- 35 kHz the spurious output measured in a 4 kHz band shall be at least 55 dB below the unmodulated carrier level. For larger frequency offsets, the spurious requirements for unmodulated carriers shall apply.

TEST III-2: RECEIVED PHASE NOISE REQUIREMENTS.

PURPOSE.

1. Validate the phase noise limitation defined in SARPs for the aircraft earth station by direct measurement on the modulated received carrier.

TEST CONFIGURATION.

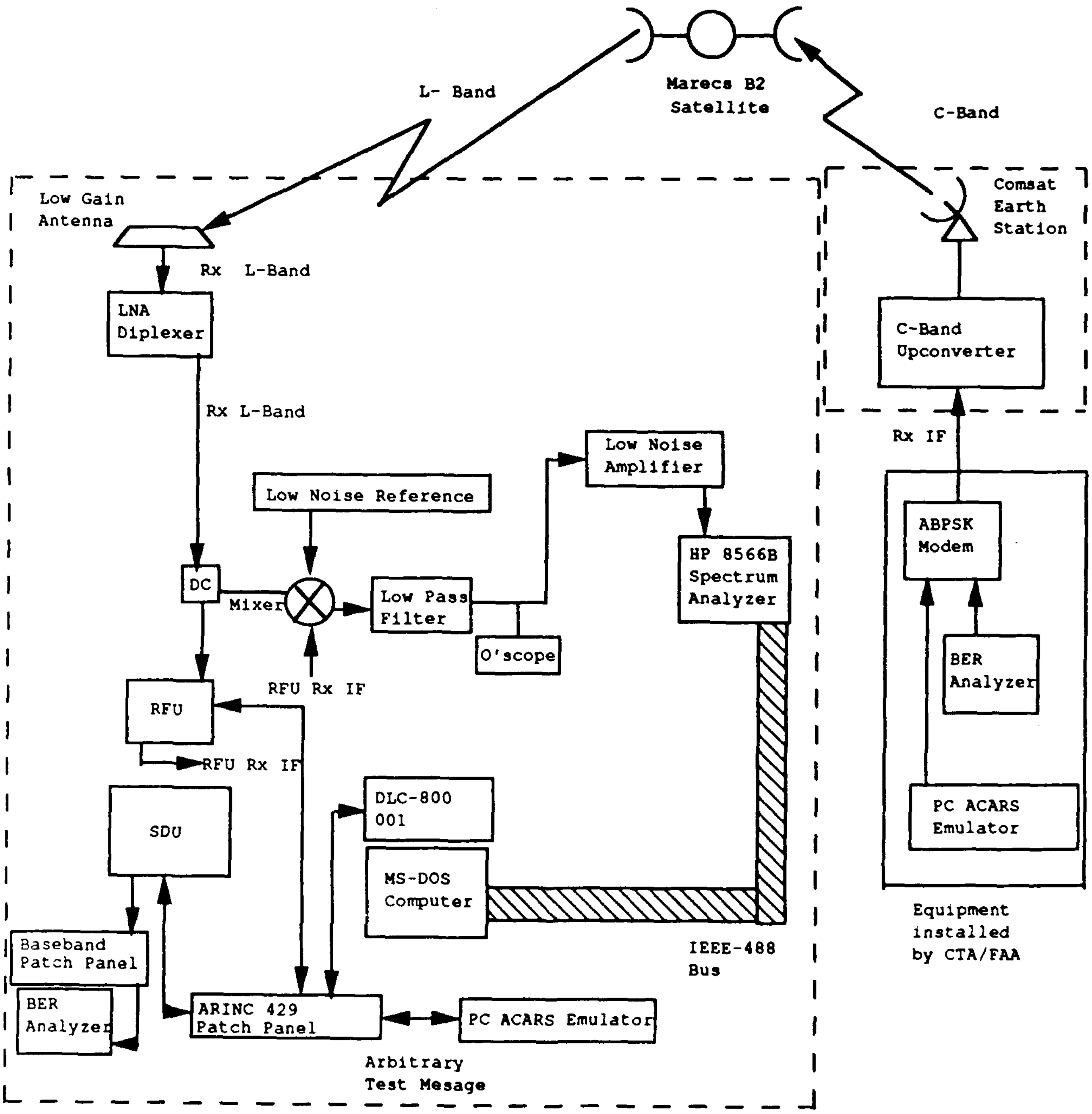


FIGURE III-2. RECEIVED PHASE NOISE MEASUREMENTS TEST ANALYSIS

TEST METHOD.

The avionics operate in normal mode. Frequencies to be tested are determined by MOA with COMSAT.

DATA RECORDED.

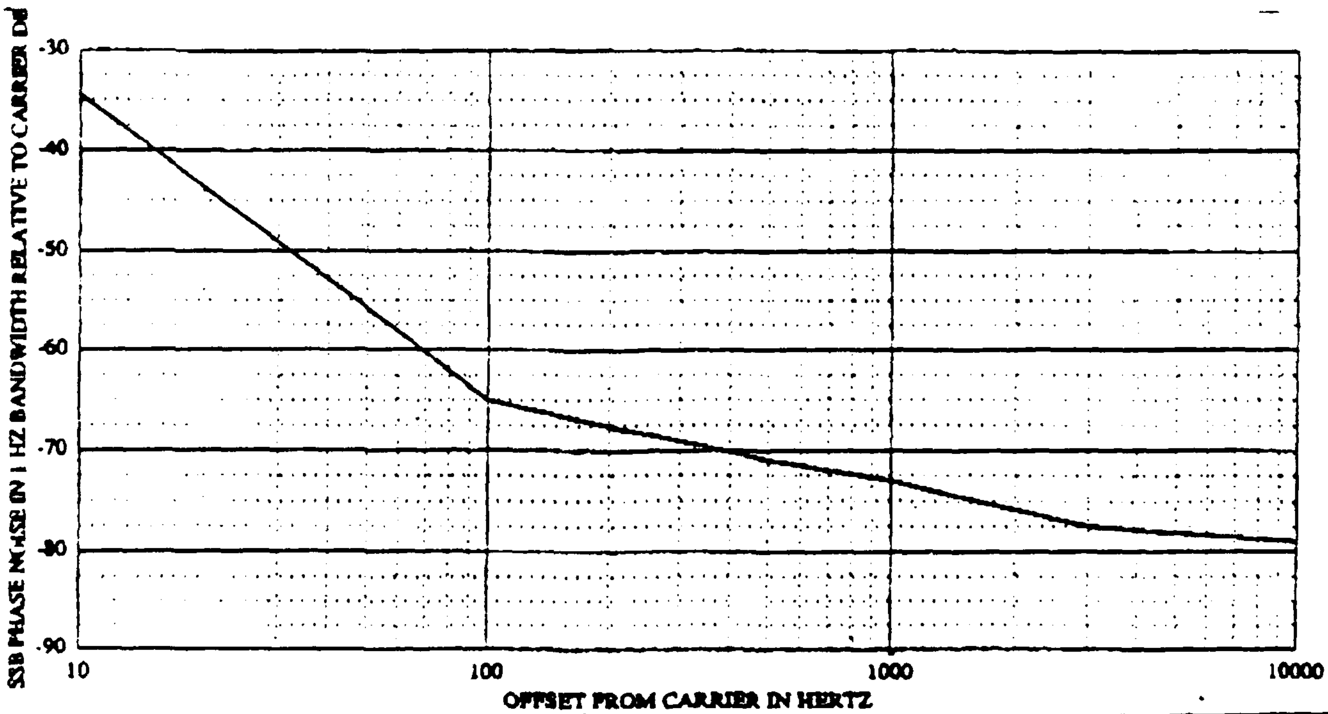
Phase noise power spectral density is measured on the modulated carrier using the HP8566B Spectrum Analyzer.

CRITERIA.

The phase noise induced on a modulated carrier must not exceed the power density given in SARPs figure III-2.1.

REQUIREMENT.

SARPs requirement 2.4.4.3 and 4.1.2 is validated by successful completion of this test and of the channel performance test (Test III-4).



TEST III-3: DEMODULATOR PERFORMANCE.

PURPOSE.

Validate the demodulator performance in the presence of two adjacent carriers 5 dB than the desired carrier.

TEST CONFIGURATION.

The test method for this requirement is under investigation. Alternative being evaluated include the use of a second set of avionics, a vector signal generator and a mixer to generate the adjacent carriers and add them to the received signal at the SDU IF input. Another method would be to have COMSAT assist us by sending us two adjacent carriers at 5 dB higher on the R and T channels and check BER. Also, it would be quite simple to simulate a multipath fade to further test overall demodulator performance.

TEST METHOD.

Currently under investigation.

DATA RECORDED.

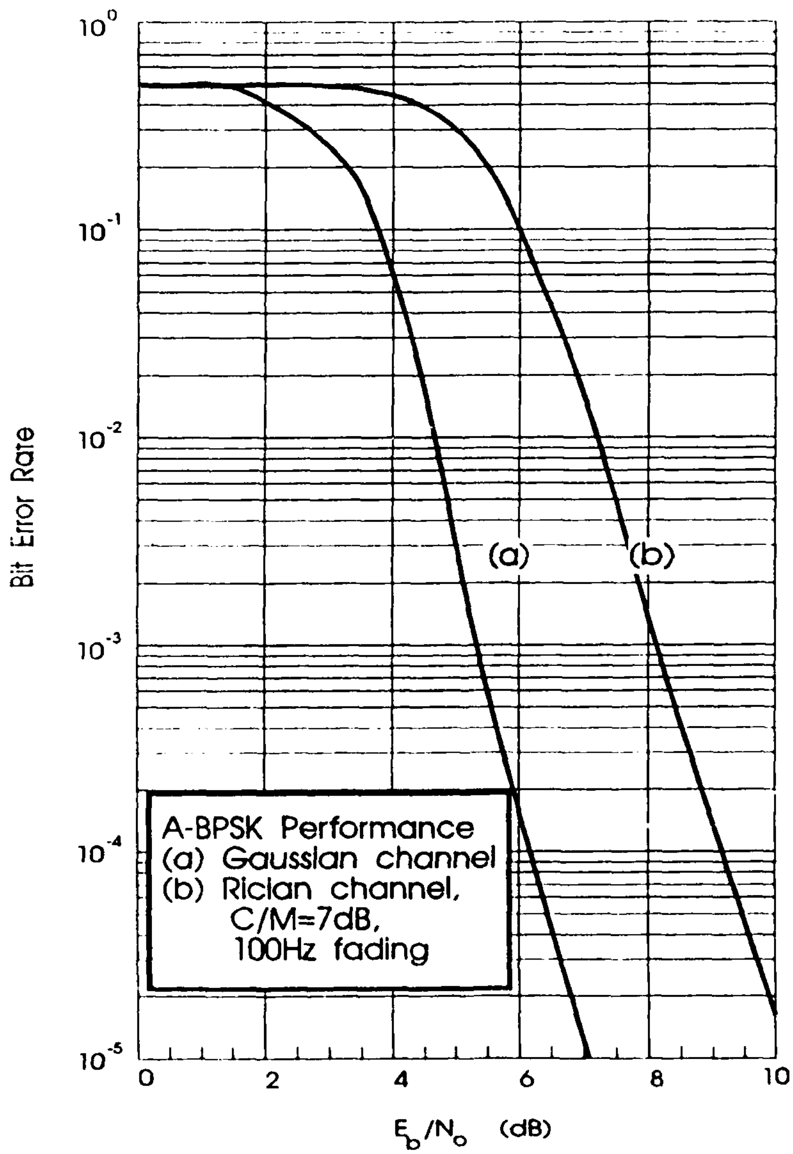
BER and signal to noise ratio shall be recorded.

CRITERIA.

The demodulator performance must meet the criteria given in SARPs figure III-3.1.

REQUIREMENT.

SARPs requirement 3.3 is validated by successful completion of this test and of the channel performance test (Test III-4).



TEST III-4: CHANNEL PERFORMANCE VS. POWER.

PURPOSE.

1. Validate the channel performance requirements defined in SARPs for the aircraft earth station for the highest, middle and lowest transmitter power settings.

2. Validate the SARPs requirements measured in tests II-1 through II-4 by noting no adverse effect on channel performance.

TEST CONFIGURATION.

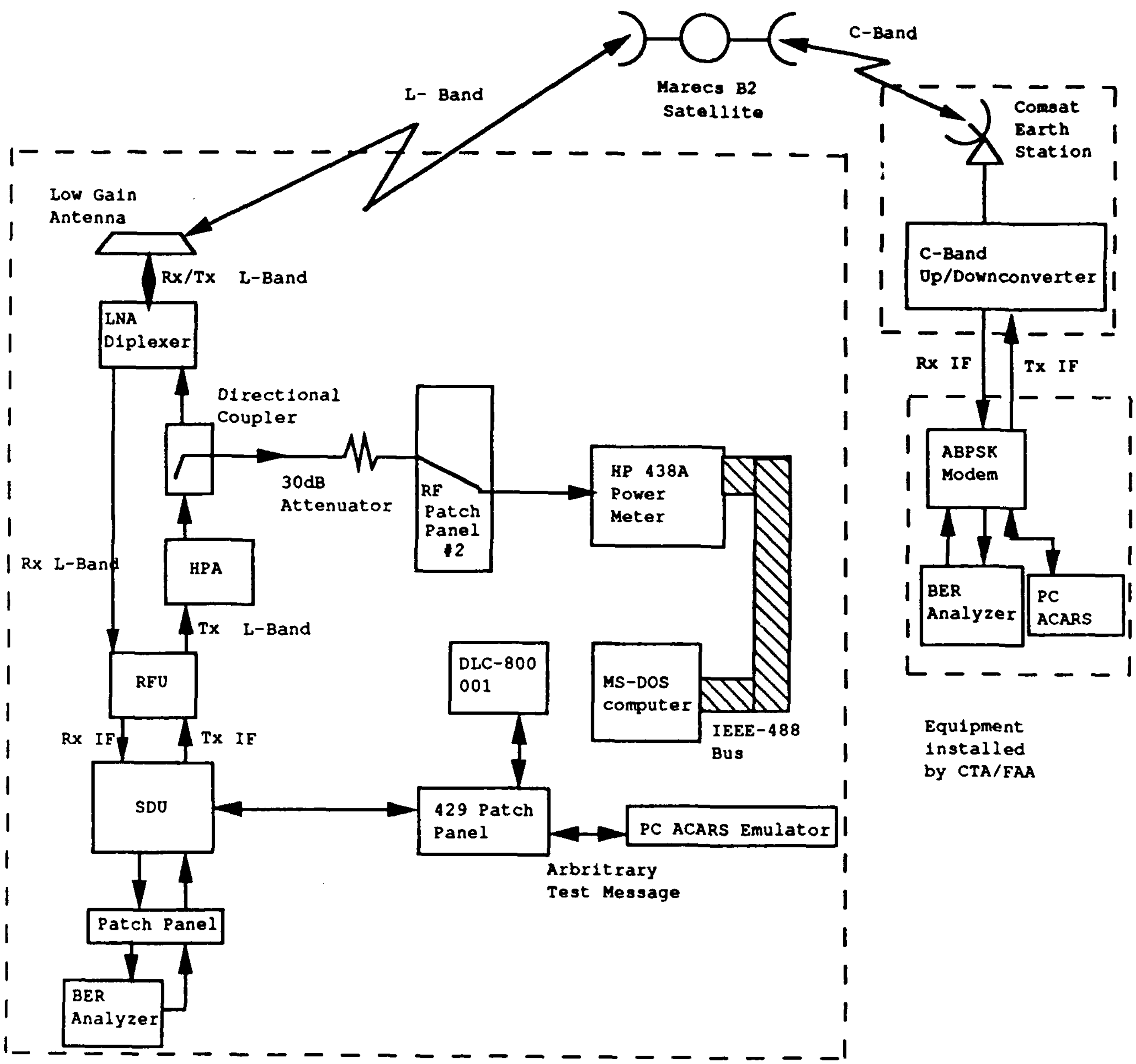


FIGURE III-4. CHANNEL PERFORMANCE VS. POWER TEST ANALYSIS

TEST METHOD.

The avionics will operate in continuous transmit mode. The power output is measured using the HP 438A Power Meter through a directional coupler at the antenna port and a 30 dB attenuator. BER measurements will be taken for HPA attenuator settings of 16 dB, 12 dB, 8 dB, 4 dB, and 0 dB at the highest, middle, and lowest frequencies in the transmit band. The exact frequencies to be tested will be determined by MOA with COMSAT.

DATA RECORDED.

1. Transmitter Power. The output power of the AES will be measured and recorded.

2. BER. BER will be measured for each commanded power setting.

CRITERIA.

The overall physical layer shall be configured such that the average BER in 10-5 or less after forward error correction.

REQUIREMENTS.

1. Channel Performance. SARPs requirement 2.4.5.8.

2. C_f Channel Number. SARPs requirement 2.1.5.2.

TEST III-5: RECEIVED SIGNAL MEASUREMENTS.

PURPOSE.

Validate the spectrum requirements and frequency accuracy defined in SARPs for the satellite/GES by direct measurement.

TEST CONFIGURATION.

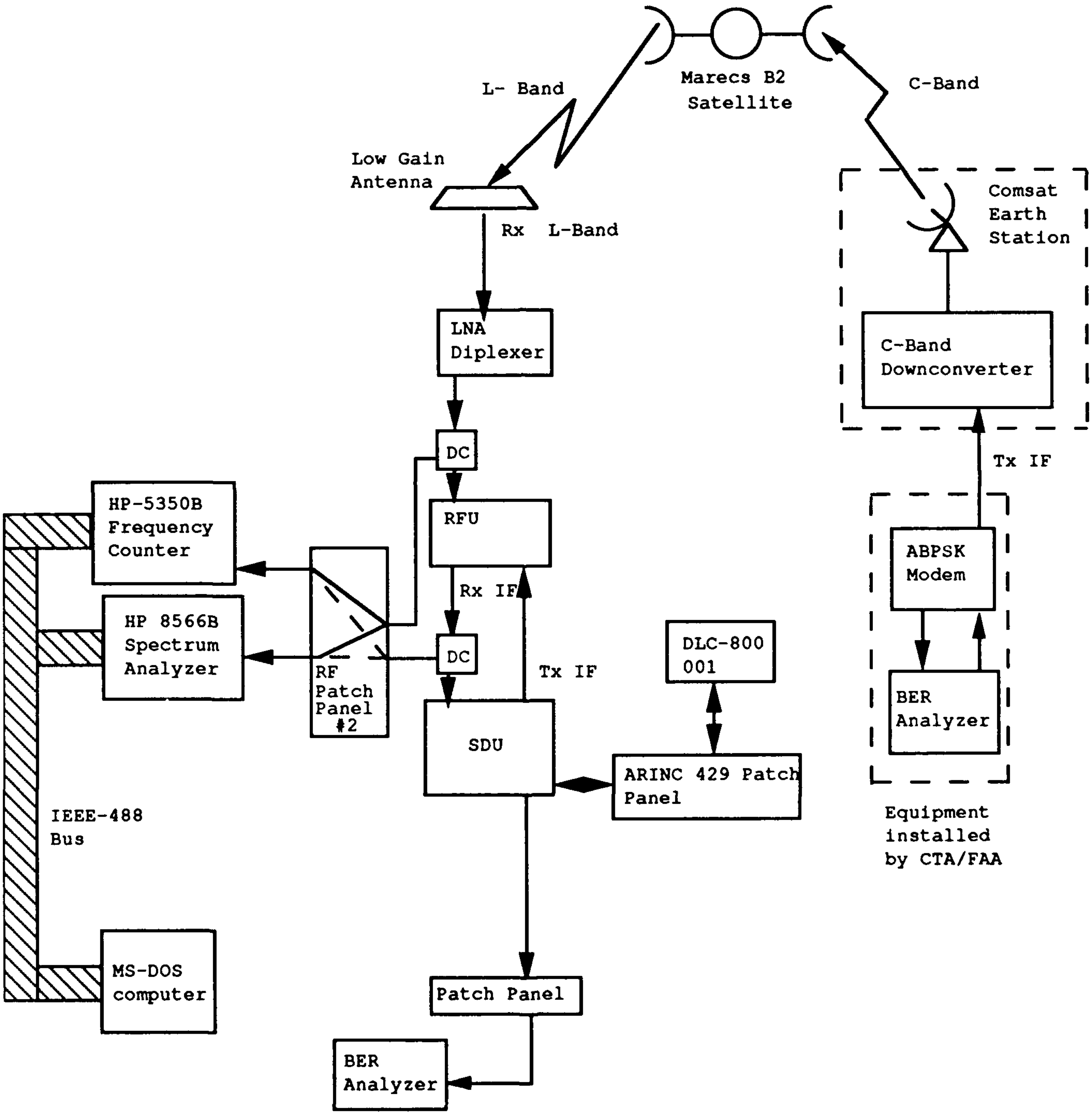


FIGURE III-5. RECEIVED SIGNAL MEASUREMENTS TEST ANALYSIS

TEST METHOD.

The avionics will operate in receive mode. The receive spectrum in measured directly at the LNA output using the HP 8566B Spectrum Analyzer. The exact frequency of the received signal will be measured by the HP 5350B frequency counter. The frequencies for testing will be determined by MOA with COMSAT.

DATE RECORDED.

1. The spectrum of the received signal will be measured for a frequency span of +/-4 times the data rate centered at the carrier frequency.

2. The frequency of the expected receive signal and the frequency of the actual receive signal will be recorded.

CRITERIA.

SARPs criteria for the above listed items are presented below.

1. The power spectrum for the signal transmitted by the GES shall be within the bounds shown in figure III-6.1.

2. The frequency of the to-aircraft signal shall be within 260 Hz of the nominal channel frequency.

REQUIREMENT.

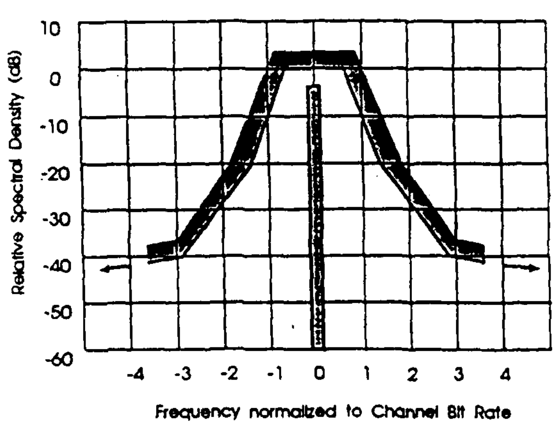
SARPs requirements validated by this test are:

1. Receive Power Spectrum. SARPs requirement 3.2.2.

2. Receive Signal Frequency Accuracy. SARPs requirement 2.2.2.1.

3. C_u Channel number. SARPs requirement 2.1.5.1.

4. Received Frequency Bands. SARPs requirements 2.1.2.1 to 2.1.2.3.



Frequency Offset (normalized to channel bit rate)	Relative Spectral Density (dB)
-35 kHz[1]	-65 dBc/4kHz
-2.8	-40
-1.4	-20
-0.625	0
-0.1	-3
0.1	-3
0.625	0
1.4	-20
2.8	-40
35 kHz	-65 dBc/4kHz

TEST IV -1. END-TO-END TIME DELAY.

PURPOSE.

To measure the time delay of a simulated ADS message over the satellite link and the ARINC data network to investigate the use of AMSS for Air Traffic Service (ATS) applications.

TEST CONFIGURATION.

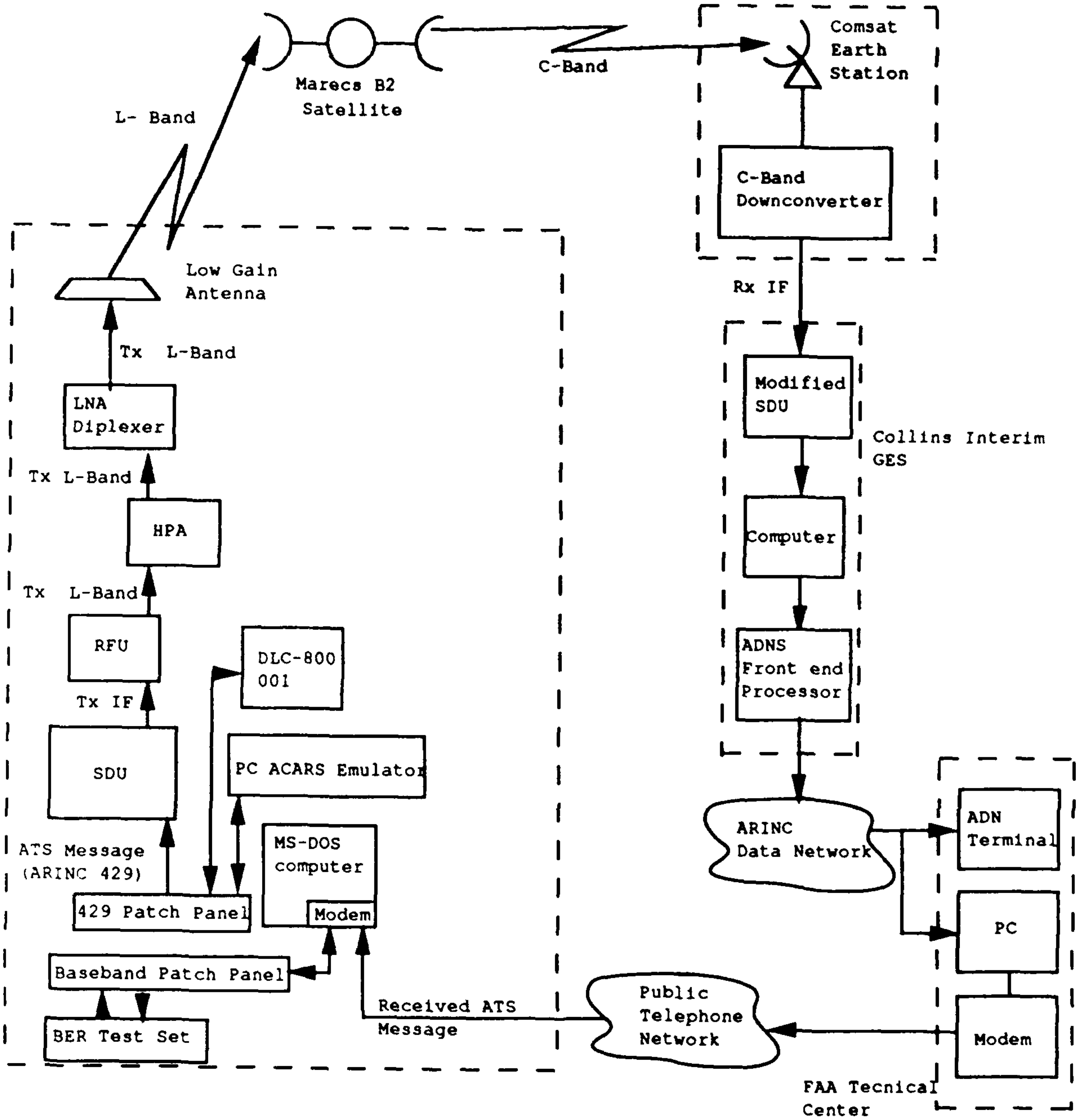


FIGURE IV-1. END-TO-END TIME DELAY TEST ANALYSIS

TEST METHOD.

The avionics transmit a short time coded message after logging on the interim GES. After the message is received at the GES, it is routed on the ADNS network to the FAA Technical Center, and from there to the CTF via public telephone network. The CTF determines time delay as it is received. An effort is made to isolate the delay of the networks from the space segment delay.

DATA RECORDED.

The time delay from the time the message is delivered to the SDU to the time it is received at the CTF is recorded.

CRITERIA.

There are no SARPs criteria for ATS message delay.

REQUIREMENT.

There are no SARPs requirement validated by this test. This test allows for the evaluation of SARPs proposals regarding message delay for ATS.

TEST IV-2: VOICE CODEC EVALUATION.

PURPOSE.

To evaluate the performance of voice CODECs intended for ATS and AOC applications over satellite link and network.

TEST CONFIGURATION.

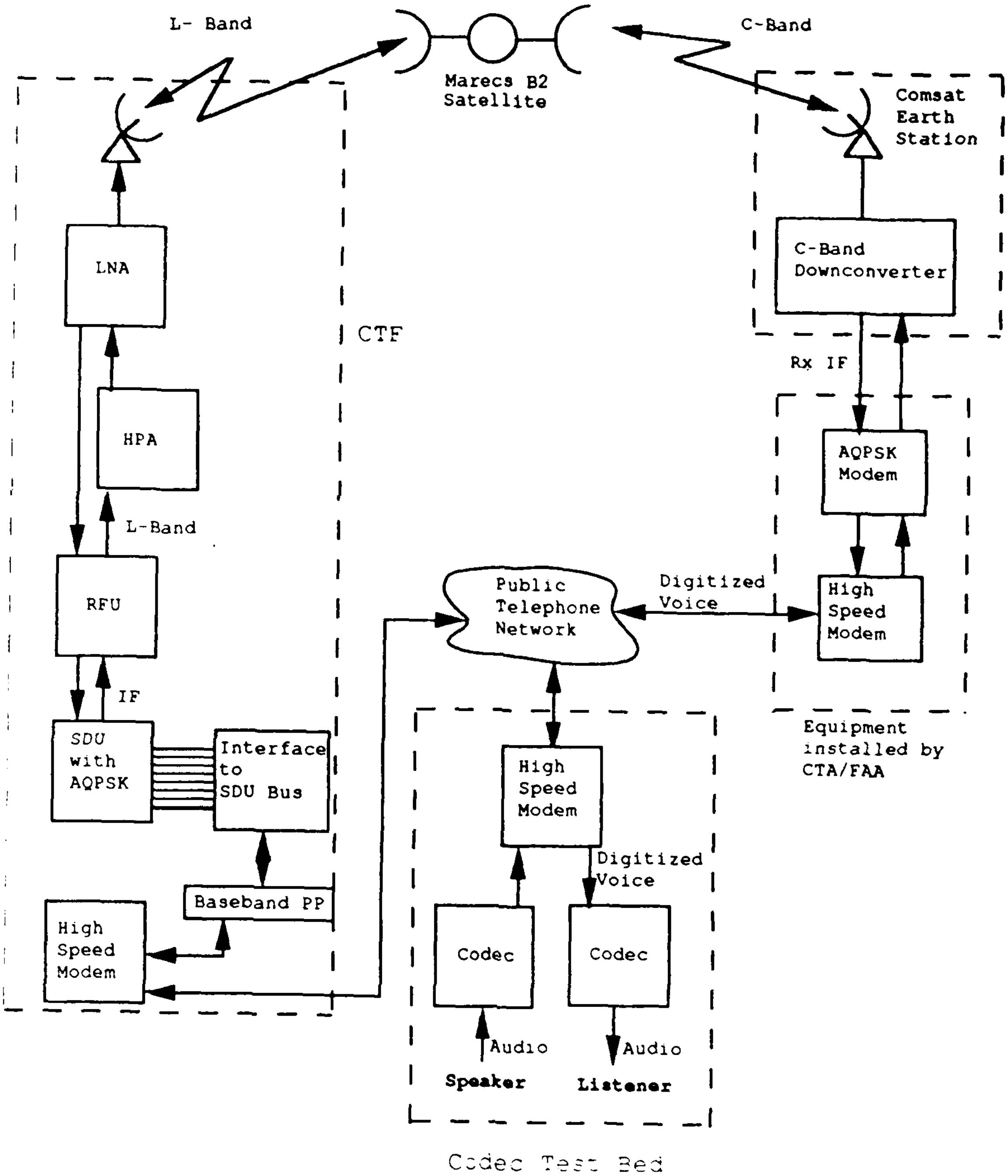


FIGURE IV-2. VOICE CODEC EVALUATION TEST ANALYSIS

TEST METHOD.

The CTF has a connection to the CODEC Test Bed (CTB) via public telephone network, or leased lines if required, to allow for the transmission of digitized voice data over satellite link. The GES will be connected to a second modem in order to send the downlinked data back to the CTB where it is converted back to speech by a CODEC.

Various CODECs are evaluated using intelligibility tests, such as the Diagnostic Rhyme Test, modified to determine their suitability for ATS communications. The tests are conducted under acoustic noise conditions in the CTB and with actual satellite link delays and degradation.

DATA RECORDED.

Intelligibility test data are recorded for various CODECs under differing conditions of acoustic noise.

CRITERIA.

The criteria for CODEC intelligibility for ATS applications are currently under development.

REQUIREMENT.

These is no SARPs requirement validated by this test. This test will allow for the performance evaluation of voice CODECs over actual satellite link and terrestrial network.

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